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VRI comparison stars for selected active galaxies

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Abstract. We present V (Johnson) and RI (Cousins) magnitudes of field comparison stars for 12 bright Seyfert galaxies. These stars are closer than 6′ (typically 3′–4′) to the galaxy and have V magnitudes between $10^{\rm m}$ and $6^{\rm m}$. The sequences could be used for CCD monitoring and differential photometry of these active galaxies, aimed to better understanding the physics of their variability. Photometric errors of measured stars are in the range $0\overset{\rm m}{.}03 - 0\overset{\rm m}{.}06$. Finding charts (15′ × 15′) are also included.

Key words: galaxies: Seyfert

1. Introduction

Although the optical continuum variability is a well known feature of a significant part of Seyfert galaxies (Dibai & Lyutyi 1984; Hamuy & Maza 1987) it is still little known about the nature and characteristics of this variability. It is important to monitor the non-blazar type AGNs (Seyfert galaxies and QSOs) because the reasons for their variability are most probably connected with instabilities in an accretion disk around a supermassive black hole, unlike the case of blazars where similar changes are usually attributed to processes in a relativistic jet (Kawaguchi & Mineshige 1998; Ulrich et al. 1997). A detailed study of Seyferts' variability can, therefore, shed some light on the accretion disk structure and properties, and respectively – on the entire mechanism of gas supply to the central engine. Useful information could be obtained only in case of systematic campaigns, revealing well the temporal behaviour of AGNs on time scales from several hours to several years. This can be realised only if efforts of different observers and observatories are involved. Here the contribution of smaller observatories, equipped with 0.5-1-m telescopes and CCD cameras, could be very important. The use of different reference stars, however, could lead to systematic shifts in the measured brightness of the variable object from one observer to another. This is especially true if broadband filters with different transparencies and cameras with different sensitivities are used.

According to our knowledge, only for a small part of Seyfert galaxies convenient comparison star fields have been calibrated so far (Lyutyj 1971; Miller 1981; Hamuy & Maza 1989). Furthermore, some of these stars are not very suitable for a differential CCD photometry either because they are calibrated only in UBV bands or because of their significant distance from the galaxy (up to 30′ or more), often exceeding the usually smaller CCD field (5′ − 15′). Comparing different calibrations, one can conclude that the photometric accuracy usually reached is not better than $0\overset{\rm m}{.}03$. More measurements made by different researches could increase that accuracy or reveal a possible long-term variability of some of the stars.

That is why we, inspired by Petrov (1988), decided to start a work for calibration of close comparison stars in V (Johnson) and RI (Cousins) bands (where most of today used CCD cameras reach their maximal sensitivity) in the fields of a large number of northern, bright (in general $V < 16^{\rm m}$) Seyfert galaxies and QSOs, selected according to Véron-Cetty & Véron (1998) catalogue. In this paper we present our first results – comparison sequences in the fields of 12 Seyfert galaxies (Table 1).

We think that the secondary standards presented here will increase (almost by 50%) the number of Seyferts with convenient comparison stars in the field. Our aim is to encourage and facilitate the CCD-monitoring of these interesting objects in order to obtain more important information about their variability.

The paper is organised as follows: in Sect. 2 observations and data reduction are presented. Section 3 contains the results and a comparison with other published data (where available). A summary is presented in Sect. 4.

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Table 1. The list of selected AGNs. Positions, other names, Seyfert types, and V-band magnitudes (V_{VCV98} and $V_{\mathrm{This\,Work}}$), both measured in 16″ diaphragm. Co-ordinates, Seyfert types and V_{VCV98} are taken from Véron-Cetty & Véron (1998). $V_{\mathrm{This\,Work}}$ is the averaged V-band magnitude, measured by us (Sect. 3)

Object	RA (2000.0)	Dec (2000.0)	Other Names	Sy type	V_{VCV98}	$V_{\mathrm{This\,Work}}$
Mkn 335	00 06 19.5	+20 12 09		1.2	13.85	14.0
Mkn 352	00 59 53.3	+31 49 36		1.0	14.81	15.0
II Zw1	01 21 59.8	−01 02 24	Mkn 1503, MCG 0-40-98	1.5	15.17	15.3
Mkn 590	02 14 33.6	−00 46 00	NGC 863, UGC 1727	1.0	13.81	14.0
Mkn 595	02 41 34.9	+07 11 14		1.5	14.69	14.8
Mkn 618	04 36 22.3	−10 22 38	MCG-2-12-45	1.0	14.51	14.7
Akn 120	05 16 11.4	−00 09 00	Mkn 1095, UGC 3271	1.0	13.92	13.9
Mkn 376	07 14 15.1	+45 41 56		1.5	14.62	15.2
Mkn 9	07 36 57.0	+58 46 17		1.5	14.37	14.7
Mkn 382	07 55 25.3	+39 11 10	MGC 7-17-1	1.0	15.50	15.5
Mkn 279	13 53 03.5	+69 18 29	UGC 8823	1.0	14.46	14.0
Mkn 315	23 04 02.7	+22 37 21	II Zw 187	1.5	14.78	14.7

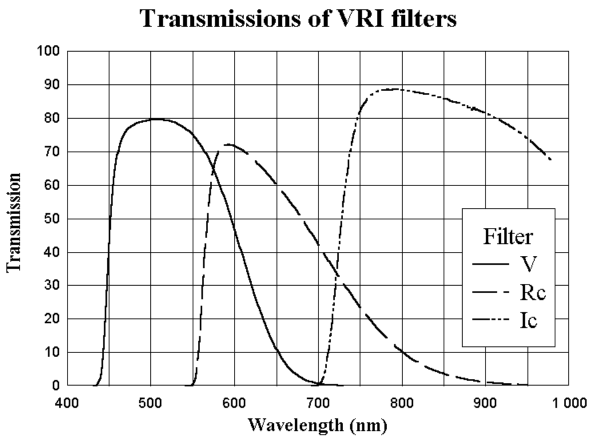

Fig. 1. Filter transmissions of the used photometric system

2. Observations and reductions

We have selected the Seyfert galaxies by the following criteria: to be brighter than 16^{m} in V-band and to have declination $> -10°$. All the objects (listed in Table 1) are classified generally as Seyfert 1 type (Véron-Cetty & Véron 1998).

Observations were performed with the 0.6-m reflector of the Belogradchik Observatory, Bulgaria (Antov & Konstantinova-Antova 1985). Red-sensitive camera SBIG ST-8 and Johnson-Cousins set of filters (Fig. 1) were used. The chip of the camera is KAF 1600 (16 bit), with dimensions 13.8×9.2 mm or 1530×1020 pixels. The size of the pixel is 9×9 μm. The scale is 27.5″/mm or 0.25″/pixel. The readout noise is 10 ADU/pixel and the gain 2.3 e^-/ADU. The camera allows binning 2×2 and 3×3. In these cases the chip is 765×510 pixels and 510×340 pixels with scale 0.50″/pixel and 0.75″/pixel respectively. In all cases the covered field is $\approx 6' \times 4'$. The camera and the equipment are described in details in Bachev et al. (1999).

During the period of two years (1998–2000) more than 700 CCD frames (including standards used for calibration) have been obtained and analysed. The typical exposure time of these frames was 120 s. We used binning depending on the seeing. Binning 2×2 was used when seeing was 2″ or better and 3×3 was used when seeing was between 2″ and 3″.

The magnitudes of the sequence stars have been calibrated using standard stars in the fields of stellar clusters – M 67 (Chevalier & Ilovaisky 1991) and in some cases NGC 7790, and M 92 (Christian et al. 1985). These fields are more convenient for use than the Landolt equatorial standards, because of the large number of stars that can be measured in a single frame. This is true especially for the high latitude observatories for which the air mass of the equatorial standards is significant even in culmination which might increase the errors of the extinction coefficients in reduction equations, and respectively – decrease the overall photometric accuracy. The accuracy of the standard stars photometry is indicated to be about $0\overset{\mathrm{m}}{.}02$ (see for instance a comparison among different measurements by Chevalier & Ilovaisky 1991). For the calibration we preferred to use mostly brighter standards ($10^{\mathrm{m}} - 14^{\mathrm{m}}$) with no companions closer than 10″.

All frames were dark subtracted and flat fielded with the standard camera's software. Photometry was performed with a code developed at the Observatory (Bachev et al. 1999). A comparison with DAOPHOT photometry routines for some of the measured stars showed no significant difference (not more than $\pm 0\overset{\mathrm{m}}{.}01$) in the instrumental magnitudes. Aperture of 12″ was used for the measurements of all stars. The observations were made in clear nights with seeing typically 2″ − 3″. For each night the standard fields were observed at least two times and a linear reduction equation was obtained for each spectral band. CCD frames with calibrated stars and standards were taken preferably with air mass and time differences as small as possible in order to diminish the influence of the atmosphere.

Table 2. VRI magnitudes and errors of photometry (see text) of comparison stars in the fields of selected active galaxies. The stars and the AGNs are indicated in Fig. 2. The number of observational epochs is given for each field ($N_{\rm Obs}$)

Object	$N_{\rm Obs}$	Star	V (σ_V)	R (σ_R)	I (σ_I)
Mkn 335	7	A	10.96 (0.03)	10.65 (0.03)	10.36 (0.06)
		B	14.25 (0.04)	13.65 (0.03)	13.11 (0.03)
		C	15.05 (0.05)	14.76 (0.04)	14.50 (0.04)
		D	15.40 (0.05)	15.00 (0.04)	14.61 (0.05)
Mkn 352	3	A	11.84 (0.03)	11.43 (0.03)	11.02 (0.06)
		B	14.71 (0.04)	14.29 (0.04)	13.87 (0.06)
		C	14.94 (0.03)	14.55 (0.03)	14.15 (0.06)
		D	15.00 (0.04)	14.63 (0.04)	14.24 (0.06)
		E	15.15 (0.03)	14.76 (0.03)	14.35 (0.06)
		F	15.40 (0.04)	15.04 (0.04)	14.66 (0.06)
II Zw 1	3	A	12.71 (0.05)	–	–
		B	12.94 (0.04)	12.60 (0.03)	12.25 (0.04)
		C	13.81 (0.04)	13.50 (0.03)	13.18 (0.04)
		D	14.89 (0.05)	14.49 (0.04)	14.08 (0.05)
		E	15.24 (0.05)	14.83 (0.04)	14.41 (0.05)
Mkn 590	3	A	11.63 (0.03)	11.39 (0.03)	11.13 (0.05)
		B	14.43 (0.04)	14.03 (0.05)	13.68 (0.06)
		C	14.75 (0.06)	14.39 (0.05)	–
		D	15.52 (0.06)	15.22 (0.05)	14.96 (0.06)
Mkn 595	3	A	13.40 (0.03)	12.94 (0.03)	12.50 (0.04)
		B	13.70 (0.03)	13.31 (0.04)	12.93 (0.05)
		C	15.30 (0.03)	14.89 (0.04)	14.50 (0.05)
Mkn 618	2	A	10.72 (0.05)	10.17 (0.04)	9.60 (0.06)
		B	11.89 (0.05)	11.37 (0.04)	10.85 (0.06)
		C	13.52 (0.05)	13.07 (0.04)	12.61 (0.06)
		D	14.49 (0.05)	14.26 (0.04)	13.87 (0.06)
		E	15.05 (0.05)	14.55 (0.04)	14.10 (0.06)
Akn 120	4	A	11.02 (0.03)	10.50 (0.04)	10.00 (0.06)
		B	12.35 (0.03)	11.81 (0.04)	11.26 (0.06)
		C	13.93 (0.04)	13.42 (0.04)	12.95 (0.06)
		D	14.67 (0.05)	14.37 (0.05)	14.10 (0.06)
Mkn 376	3	A	12.99 (0.03)	12.59 (0.03)	12.21 (0.04)
		B	13.65 (0.04)	13.16 (0.04)	12.73 (0.05)
		C	14.03 (0.04)	13.63 (0.04)	13.28 (0.05)
		D	15.82 (0.06)	15.45 (0.05)	15.05 (0.05)
Mkn 9	3	A	12.09 (0.03)	11.69 (0.03)	11.32 (0.05)
		B	12.76 (0.04)	12.23 (0.03)	11.74 (0.05)
		C	13.37 (0.03)	12.94 (0.03)	12.56 (0.05)
		D	15.27 (0.04)	14.89 (0.03)	14.55 (0.05)
		E	15.94 (0.04)	15.49 (0.03)	15.10 (0.05)
Mkn 382	2	A	10.09 (0.03)	–	–
		B	13.41 (0.03)	12.82 (0.03)	12.29 (0.04)
		C	13.48 (0.03)	13.00 (0.03)	12.59 (0.03)
		D	14.62 (0.03)	14.24 (0.03)	13.89 (0.03)
Mkn 279	7	A	12.11 (0.03)	11.55 (0.03)	11.04 (0.04)
		B	12.96 (0.03)	12.53 (0.03)	12.16 (0.04)
		C	14.89 (0.04)	14.32 (0.03)	13.79 (0.04)
		D	15.59 (0.04)	15.15 (0.03)	14.76 (0.04)
Mkn 315	6	A	11.00 (0.04)	10.59 (0.03)	10.18 (0.05)
		B	15.93 (0.05)	15.49 (0.03)	15.05 (0.05)

Table 3. Comparison between different calibrations

Work		Miller 1981	Hamuy & Maza 1989			This paper		
Object	Star	V	V	R	I	V	R	I
Akn 120	A	–	11.07	10.53	10.06	11.02	10.50	10.00
	B	12.42	12.38	11.82	11.29	12.35	11.81	11.26
	C	13.96	13.91	13.39	12.91	13.93	13.42	12.95
	D	14.68	14.68	14.34	14.01	14.67	14.37	14.10
Mkn 315	A	10.97	–	–	–	11.00	–	–
	B	15.95	–	–	–	15.93	–	–

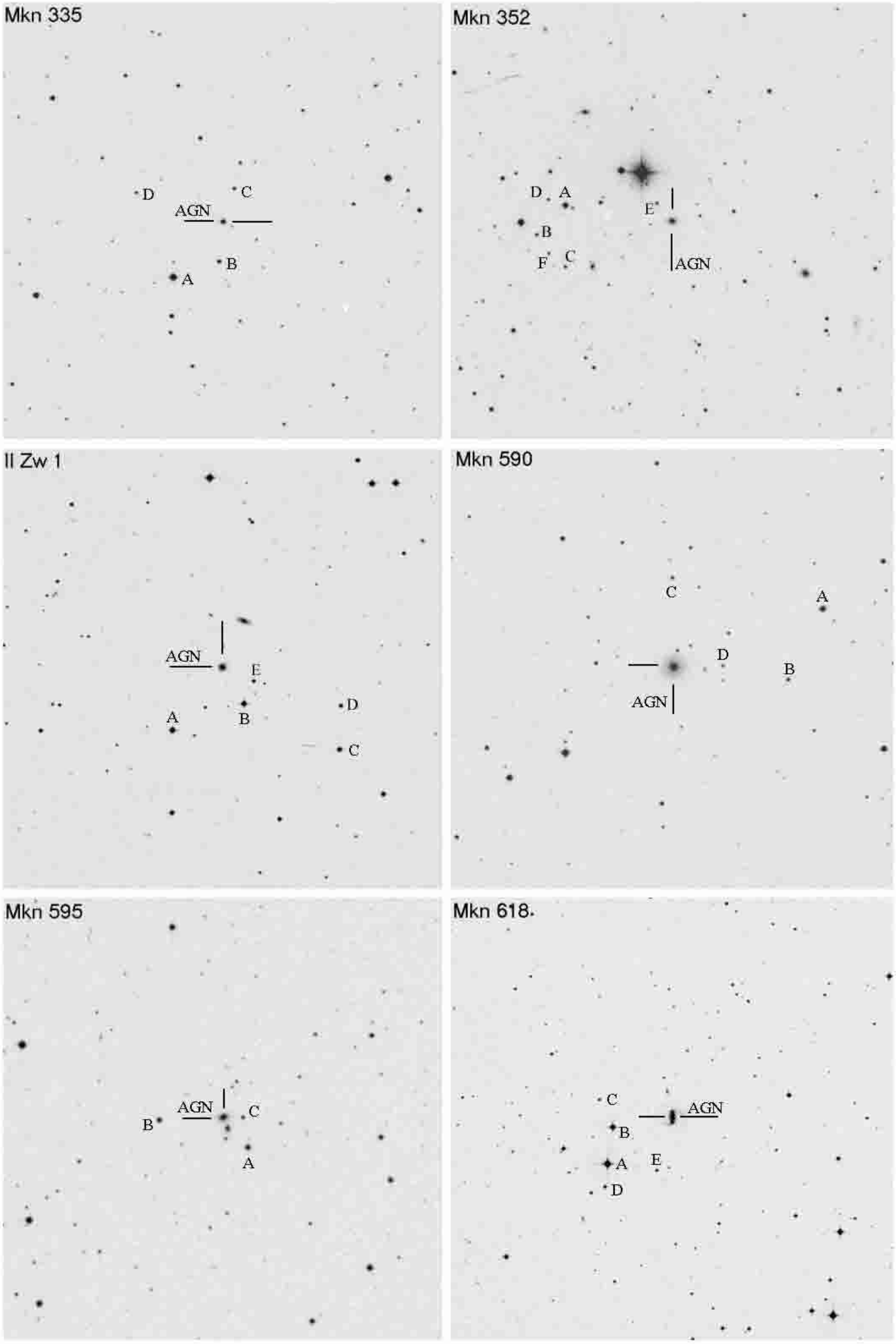

Fig. 2. Finding charts for selected Seyfert galaxies. The field is 15′ × 15′, centered on the AGN's position. North is at the top and east to the left. All charts are retrieved from the STScI Digitized Sky Survey

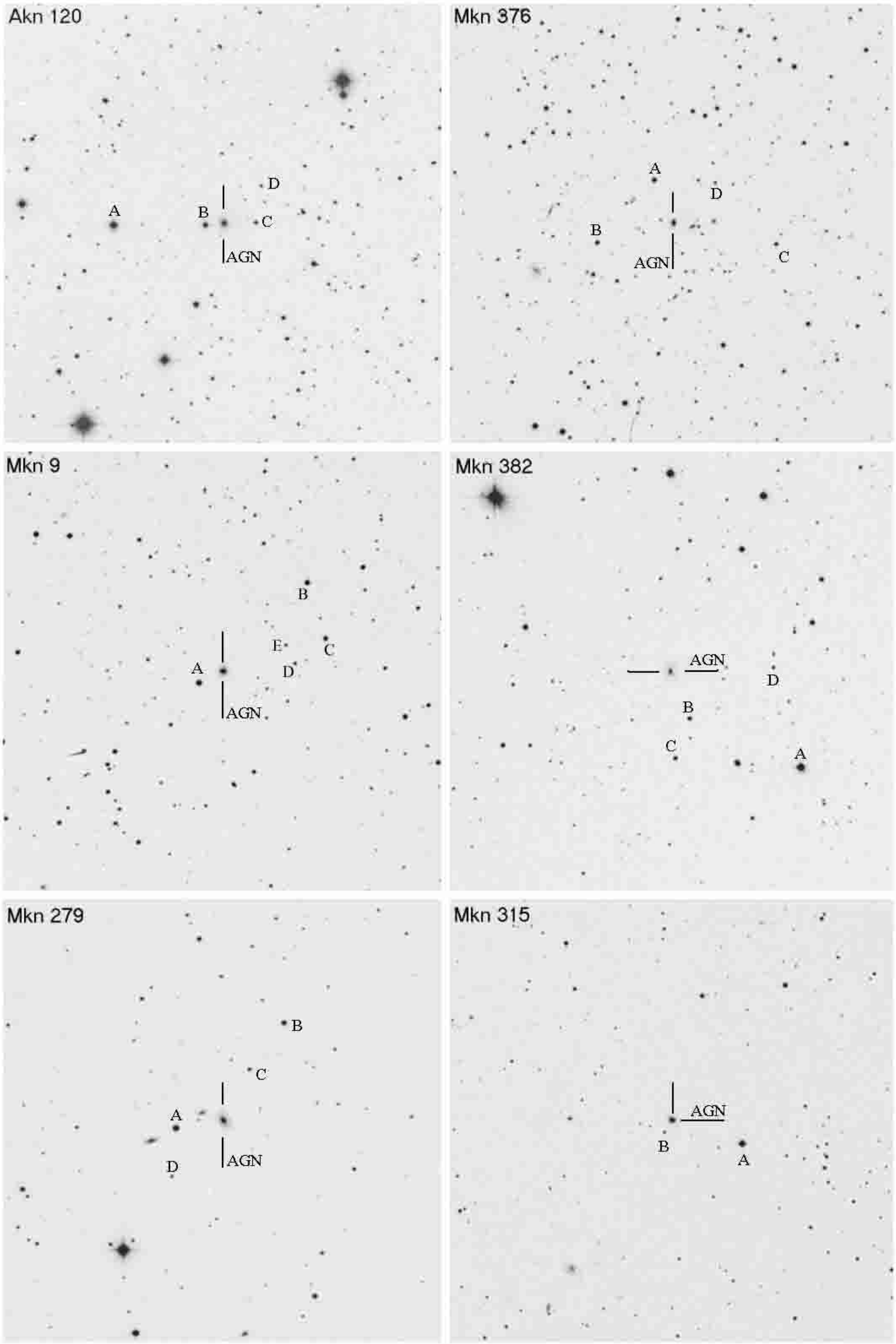

Fig. 2. continued

3. Results

Finding charts with field $15' \times 15'$ for all observed sequence stars are presented in Fig. 2. The charts were retrieved from the STScI Digitized Sky Survey. North is at the top and east is to the left. On each chart the secondary standards and the Seyfert galaxy are indicated. All the sequence stars are closer than $6'$ (typically $3' - 4'$) from the Seyfert galaxy. Their brightness is between $10^{\rm m}$ and $16^{\rm m}$. VRI magnitudes for all measured stars are listed in Table 2. The stars are labeled A, B, C... in order of their V-band magnitude. Errors of the photometry (a square root of the sum of squares of the dispersion of the total magnitude as a mean of different observational runs and the error of calibration, which is about $0\overset{\rm m}{.}02 - 0\overset{\rm m}{.}03$) are given. The magnitudes of stars around the active galaxy were measured in usually $3-4$ photometric nights (Table 2). No variable stars (within $\pm 0\overset{\rm m}{.}03$) among the selected sequence stars have been detected by means of differential photometry with other stars in the field.

We found photoelectric calibrations (published after 1980) for several stars from our list (Miller 1981; Miller 1986; Hamuy & Maza 1989). A comparison with our measurements is presented in Table 3 and shows a good agreement between the magnitudes, assuming photometric errors of about $0\overset{\rm m}{.}03 - 0\overset{\rm m}{.}04$. It should be pointed out that the observers have used different photometry diaphragms in their measurements $-12''$ – in this study, $17''$ – by Hamuy & Maza (1989).

We measured V-band magnitudes of all Seyferts in a $16''$ diaphragm (Table 1) in order to compare these magnitudes with those given by Véron-Cetty & Véron (1998) for the same diaphragm. The comparison shows clear indications for variability in some of the objects (Mkn 9, Mkn 279 and Mkn 376). It should be taken into account, however, that we subtracted the background using an annulus located just outside the photometry diaphragm while in photoelectric observations usually the background contribution is measured far from the object of interest. In our case this might slightly overestimate the measured magnitudes (for these objects – not more than $0\overset{\rm m}{.}1$). In more details we explored the broadband variability of three objects – Mkn 279 (Bachev 2000), Mkn 315 and Mkn 335 (Bachev & Slavcheva-Mihova 2000). Monitoring of the other galaxies is continuing and the results will be published elsewhere.

4. Summary

In this paper we present accurate photometry (V Johnson and RI Cousins) for 50 stars, in the fields of 12 bright Seyfert 1 galaxies, suitable for calibration purposes in obtaining differential photometry and therefore for variability studies. These stars are brighter than $16^{\rm m}$ and are located at distances smaller than $6'$ from the AGN. The accuracy of our photometry is $0\overset{\rm m}{.}03 - 0\overset{\rm m}{.}06$. Finding charts for all stars and AGNs are given. We hope that these standards could be useful for optical monitoring of Seyfert galaxies that could be performed successfully even with telescopes with diameter of the mirror $0.5 - 1.0$-m.

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